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Interstratified illite–smectite phases: formation mechanisms and practical applications

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Abstract

Secondary micas after smectite, including mix illite–smectite phases, can form in sediments by three mechanisms, each being specific to particular environments. As the process develops, the newly formed phases undergo structure ordering. Two mechanisms involve transformation of 2:1 mixed-layer structures, and the third is the growth of screw dislocations, with formation of ordered mix phases having a Reichweite parameter of $R = 1$ or $R = 2$. We propose methods for identifying such phases when they are present in small amounts or when their XRD patterns lack well-pronounced superperiodic reflections, as well as mathematical formalism for illitization modeling. The theoretical issues are illustrated with field examples, and the illitization mechanisms are discussed in terms of their possible practical applications.

Keywords: XRD analysis; structure; interstratified illite–smectite phases

Introduction

Conversion of smectite to illite (illitization) is a global process common to all sedimentary strata. It is assumed to be basically a single event induced by pressure and temperature increase upon progressive burial of sediments. It occurs by the dissolution–precipitation mechanism (Drits and Sakharov, 1976; Šrodoń et al., 2000; Drits et al., 2007), whereas the 2:1 layer structure remains invariable in the case of hydrothermal processes (Frank-Kamenetsky et al., 1983). Illitization includes the formation of interstraified illite–smectite (I/S): first disordered mix phases, at $R = 0$, then ordered mix phases at $R = 1$ and then $R = 2$, where R is the Reichweite parameter (German for *range* or *reach*). According to transmission electron microscopy (TEM), however, particles of I/S phases with different R values may coexist in one sample (Dong et al., 1997).

Later other illitization mechanisms were suggested, such as direct conversion of smectite into illite, skipping he intermediate I/S phases (Krinari and Khramchenkov, 2005; Solotchina, 2009), and the dislocation growth mechanism for illite crystals (Krinari and Khramchenkov, 2008). Furthermore, illite particles show both normal and lognormal distributions of measured thicknesses instead of normal distribution only, thus indicating more than one illitization mechanisms (Dudek et al., 2002).

The inconsistency stems from the wrong assumption that the smectite–illite transition inferred for mature sediments with high P-T parameters would be universal and applicable to low-grade sedimentary rocks. The structure of fine illite–smectite phases should be analyzed with special X-ray diffraction methods.

Experimental methods for studying the structure of interstratified illite–smectite phases

The experiments were applied to the ≤2.5 μm fraction extracted from dry or originally water-bearing samples of reservoirs D_1 and D_0 at the Romashkino oil field in West Siberia, as well as from Neogene and Upper Permian clay samples from Tatarstan. Both basal (00l) and other diffraction spectra were collected from oriented specimens. The (00l) reflections were recorded in air-dried material saturated with ethylene glycol, on the 1/Å linear scale, in the range from 0.002 to 0.405 1/Å (x axis), at a step of 0.0008 1/Å. Thus we culled out samples containing kaolinite together with mix phases with a high proportion of smectite, which produce separate reflections in glycolated clay.

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